SOURCES OF RADIANT ENERGY FOR MEDICAL USES

Investigative Needs*

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Any attempt to outline critical needs in a field as broad as that concerned with sources of radiant energy must certainly be heavily influenced by the interests and experience of the reviewer. Accordingly, the comments and suggestions presented here reflect the problems encountered by the author, and will, in all likelihood, cover only a segment of the many lines of investigations that are possible.

As an introductory example it might be well to examine an often quoted statement, that what is most needed in clinical medicine is an "artificial source of light, corresponding as closely as possible to natural sunlight." Assuming this to be the case, it is first necessary to define what is meant by "natural sunlight." The solar spectral energy above the stratosphere? Then the source would have to emit all wave-lengths from seven angstrom units (x-ray) to several centimeters. The solar spectral energy on top of the atmosphere? That would mean a spectrum reaching from 2000 to 26,000 Å. Assuming it to mean the energy reaching the earth's surface, great differences in the breadth of the wavelength band (with lower limits reaching from 2900 to 3200 Å) and of intensity (ten times more energy at noon in summer than in winter) have been reported. Adding to this the variations in types of radiation and intensity due to differences in elevation above sea level, atmospheric pollution, angle of incidence, mobility of the subject, etc., the term, "Natural Sunlight" becomes almost impossible to define. Even if a "sun" could be produced in the laboratory, it is unlikely that it would be useful to the practicing physician, if only because the energy output in the biologically active ultraviolet would be so low as to require exposures of many minutes to produce useful effects. For example, using the standards proposed by the Council of Physical Medicine of the AMA, it would take from five to ten minutes to deliver a minimal erythema dose, much more if winter sun is used as a reference source.

It thus appears necessary to define more precisely the segment of the electromagnetic spectrum which is of medical interest, and then discuss sources able to emit the proper combination. In the following discussion, only the ultraviolet band, reaching from 1800 to 4000 Å will be considered, with full realization that the longer and shorter wavelengths may have uses which cannot be discussed in the framework of this Symposium.

It is generally accepted that ultraviolet rays have at least four major effects: 1) chemical, 2) bactericidal, 3) erythema and pigment production and 4) carcinogenic. From the point of view of the physiologist, the chemical and bactericidal effects of ultraviolet are of relatively minor interest. The last two effects named are however of great importance to the clinician and experimenter alike, and it may be of interest to note that the wave bands producing such manifestations overlap.

The problem of defining in exact fashion what effect individual portions of the ultraviolet spectrum have on living tissue has been made difficult by the property of available light sources to give out discontinuous wave bands, or of having isolated peaks at some frequency or other if they emit a continuous spectrum. The ideal light source for the type of studies I shall propose a bit later, would have to have two major properties: 1) A continuous spectrum covering a range from 1800 to 4200 Å, with provisions to project at will only a very narrow band width (say 2–3 Å wide), or to project a band equally evenly producing this spectrum, and 2) a sufficiently high intensity, subject to controlled regulation by the experimenter, to produce adequate biologic effects on living tissue. That would mean an output in the range of 1×10^6 ergs/cm².

Obviously such a source is presently not available. Possibly the new pinch tubes generating

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temperatures above five million ° C., if perhaps fitted with sapphire windows, might qualify in this category. Regulation of band width can be accomplished by such methods as filters, diffraction gratings or slits—it is the principle on which the spectrophotometers are built. But the really large problem arises in achieving sufficiently high output for a sufficient time. Certain spectral lines emitted by gas discharges or metallic arcs can be produced with sufficient intensity—such as the 2537 line of mercury, etc.—but there are huge gaps in the available equipment.

The second great need is that of finding a suitable, simple, cheap and accurate means of measuring the output of a source at these various wavelengths. For the ideally controlled experiment, the wavelength band emitted should be well defined, and the amount of energy reaching the tissue should be accurately measurable.

Having posed such a very difficult problem to the engineer and the physicist, it seems reasonable to expect to tell them to what uses such equipment could be put.

The present state of ultraviolet carcinogenesis may serve as a useful example: Until a few years ago, it was thought that wavelengths shorter than 2800 Å did not produce skin cancer. Now it appears clear from the studies of Rush *et al.* (1), O'Neal and Griffin (2), Kelner (3) and F. Urbach (4), that the shorter ultraviolet contributes greatly to experimental ultraviolet carcinogenesis in mice. Whether wavelengths longer than 3100 Å also contribute to this effect, is not yet known. Using my theoretical "ideal" light source, a systematic inquiry into the relative carcinogenic effect of the entire spectrum could be made.

This becomes even more important if one considers the demonstrable co-carcinogenic effect of some photosensitizers such as methoxsalen, which will be discussed in subsequent papers. There is some preliminary evidence that photosensitization with this compound can be produced at 3660 Å (5), and even beyond. This raises the question whether such long ultraviolet, in the presence of a photosensitizer, may be carcinogenic.

Having examined the type and need for an "ideal" source of radiant energy, a little time may be spent on the shortcomings of present equipment. Commercially available sources of ultraviolet may be roughly divided into: 1) open arcs (carbon, carbon-metal), 2) enclosed vapor arcs (mercury arc lamps), 3) metal vapor discharge lamps ("Sun" Lamps—RS1, etc.) and 4) "fluorescent sun" lamps (sterilamps, etc.).

Only a few of the problems encountered with each of these types of sources will be mentioned here. Open arcs are cumbersome, expensive to operate and maintain, and difficult to calibrate. Their advantages are that they emit a continuous spectrum, which can be altered to a certain degree by varying the metallic core of the carbons, and that they have a high intensity of output. Enclosed mercury vapor arcs of high pressure type emit very large quantities of biologically active wavelengths. But the quartz envelopes change under continuous intense radiation, resulting in a great and unpredictable change in energy output and in spectral arrangement. Furthermore, the mercury arc does not give out a continuous band of ultraviolet, but rather shows well defined lines, and more than three-quarters of the energy produced lies in the very short ultraviolet below 2800 Å.

Metal vapor discharge lamps are generally inexpensive, but of very low intensity, and not well suited for experimental work. The final category, fluorescent "sun" lamps, have as yet been little used for animal and human experiments. In our experience they have many advantages over more conventional high and medium pressure mercury arcs, and over carbon open-type arcs. The experiments to be reported later concerning ultraviolet carcinogenesis, were performed with such a source (Westinghouse type FS40T12). The radiation from this lamp very nearly approximates the short radiation of the sun, with a wavelength range from 2750 to 2800 Å, and a distinct peak between 2950 and 3200 Å. The lamps are inexpensive (a fixture with four lamps costing about $65), no warmup is required, their output is continuous, and we have observed no change in spectrum or loss of efficiency in our unit after 600 hours of operation. From the point of view of the experimenter, there are additional, less obvious advantages to the fluorescent "sun" lamps. There is no heat production (a major problem in animal studies using mercury or carbon arcs), and little or no ionization of the atmospheric air. This may be of great importance in studies of carcinogenesis, since there is now some evidence that negative ions in the air may adversely affect cancer induction (6–8).

Finally, these lamps have been used clinically

(9), and it appears that they compare favorably with standard mercury arcs as far as time to produce erythema and pigmentation is concerned.

In summary, the problems concerning available and needed types of ultraviolet sources for investigational use have been discussed. It appears that there is a real need for a type of ultraviolet emitter embodying the factors of continuous spectrum, ability to isolate and project at will narrow bands of the ultraviolet of high intensity, and machinery to measure exactly the output of such a source. Of the available emitters, the fluorescent "sun" lamps seem to have come closest to the short radiation from the sun, are inexpensive, easy to operate, can be calibrated exactly and show little change of spectrum or intensity with time. Wider use and study of the biologic applications of this type of ultraviolet emitter is seriously recommended.

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